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MEMORANDUM REPORT NO. 1457
MARCH 1963

70 GC KLYSTRON FREQUENCY STABILITY AND SPECTRUM

John E. Kammerer
Cecil L. Wilson

RDT & E Project No. 1M222901A215

BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

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MEMORANDUM REPORT NO. 1457

JEKammerer/CLWilson/cet
Aberdeen Proving Ground, Md.
March 1963

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ABSTRACT

Measurements were made of the frequency stability of V-band reflex klystrons while being operated from regulated voltage sources of different stability. A. C. line regulators and two different types of power supplies were used; one with a voltage regulation of 0.03%, and the other with a voltage regulation of 0.001%.

Relative frequency stability was determined by mixing the outputs of two klystrons whose frequencies differed by approximately 60 mc. This difference frequency was then amplified, counted on a high-frequency counter, and observed on a panoramic receiver.

I. INTRODUCTION

Certain measurements of the frequency stability of 70 Gc reflex klystrons were made to determine the bandwidth of the output signal and the sensitivity of the klystrons to variations in supply voltages. All measurements were of the comparison type accomplished by operating two klystrons at nearly the same frequency and recording the stability of the difference frequency.

A servo loop fed back into one of the reflector voltage sources was tested for ease of locking and the increase in stability over the free running klystrons. The servo stabilizer was particularly effective in eliminating slow frequency drift over an extended period.

II. COMPONENTS

A. Frequency Measurement

Two Raytheon QKK837 klystrons were operated in the recommended mode and their output fed into a crystal mixer. The mixer used a Philco 1N2792 crystal diode. The difference frequency between the klystrons was set at approximately 60 mc. A 60 mc IF amplifier provided sufficient voltage gain of the signal from the mixer to drive a frequency counter. The frequency counter used was the Hewlett-Packard Model 524B with the 525A Frequency Counter Head. The 524B has a counting accuracy of $\pm$ 1 count with a time base accuracy of $\pm$ 1 part in 10^6 with a minimum input voltage requirement of 0.1 volt rms. An external reference frequency of 100 kc was provided the counter by a Borg Radio Frequency Standard having a stability of 1 part in 10^8 in 60 days. Digital print-out of the difference frequency was recorded by a Hewlett-Packard Model 560A Digital Recorder.

Two power sources were used with the klystrons. An FXR Inc. Klystron Power Supply, Type Z815-B with a single output regulated to 0.03% and a PRD (Polytechnic Research and Development) Klystron Power Supply Type 812 having two parallel outputs regulated to 0.001% were used. The line input to each power supply was regulated, where noted, by a Sorensen Line Regulator Model 2000-5 to 0.1%.

B. Spectrum Analysis

The equipment described above was used in conjunction with the Panoramic Radio Products, Inc. Spectrum Analyzer Model SPA-1 and tuning head RF-2. Observations over a 10 mc bandwidth on each side of the 60 mc center frequency were made. Sensitivity of the analyzer at 60 mc was -100 dbm. Gain was variable from 0 to 40 db. Scanning rate was continuously variable from 1 to 60 cps.

An Automatic Frequency Control (AFC) circuit, designed, fabricated, and calibrated in the laboratory, was used to effect control over the frequency drifting between the klystrons. The time constant of the AFC circuit was about 0.1 second and control was maintained over a 2.5 mc bandwidth centered about 60 mc. The AFC circuit controlled the reflector voltage of the FXR power supply to maintain the difference frequency at a pre-selected value.

A Polaroid camera with a 75 mm lens was used to photograph the frequency difference spectrum as displayed on an oscilloscope.

III. TEST SET-UP

A. Frequency Measurement

The test equipment was interconnected as indicated in Figure 1. Standard V-band (50 - 75 Gc) waveguide components such as isolators, loads, magic Tees, 90° twists, frequency meters and attenuators were used. A vacuum tube voltmeter was used on the discriminator output as a visual indicator for the presence of the difference frequency within the 60 mc bandpass of the amplifier.

B. Spectrum Analysis

The test equipment was interconnected as indicated in Figures 2 and 3. Two vacuum tube voltmeters were used as visual indicators; one to monitor the presence of the difference frequency at the output of the IF amplifier, the other to detect the discriminator output.

IV. TEST PROCEDURE

A. Frequency Measurement

Three long time counts of the difference frequency were made to record the magnitude of the frequency drift resulting from three methods of powering the klystrons. One klystron was powered by the PRD klystron supply on each test. The other klystron was powered by 3 different methods; first, by the FXR klystron supply without line regulation; second, by the parallel output of the PRD power supply; and third, by the FXR supply with a regulated line voltage.

Each klystron was operated in its recommended mode on C. W. power and peaked independently of the other except in the case when both klystrons were powered by the parallel output of the PRD supply in which case a compromise in voltage adjustments was made. No interaction between the klystrons was observed. A four hour warmup period was allowed for each test.

Since the voltage out of the mixer corresponding to the difference frequency was not sufficient to drive the counter, the 60 mc IF amplifier was required to supply the necessary voltage. The difference frequency was tuned to 60 mc by mechanically adjusting the frequency of one of the klystrons (No. 17) after a rough approximation of each klystron frequency was obtained by means of the frequency meters which were readable to 10 mc.

A print-out time of 1 second was used with the counter and the display time was adjusted to allow sufficient time for the Digital Recorder to print out the frequency information.

Each test was of 15 minutes duration. During this period, several checks were made to ascertain that the counter was operating properly. The 100 kc standard frequency of the Borg unit was also monitored. No adjustment of klystron beam, reflector, grid, or filament voltages was made during the test runs.

During the 4 hour warmup period of the third test, the difference frequency was monitored. At intervals of at least 15 minutes, the frequency of each klystron was measured by means of Technical Research Group frequency meters. After two hours of warmup, the difference frequency was printed for 15 minutes by the digital recorder. Adjustment was required several times to keep the difference frequency within the bandpass of the 60 mc IF amplifier.

The frequency drift information obtained during the warmup period of the third test was used to determine the frequency deviation of the klystron from a cold start.

B. Spectrum Analysis

One klystron was powered by the PRD supply and the other by the FXR supply with regulated line voltage. The difference frequency signal from the mixer was amplified and fed to the analyzer after a four hour warmup period.

The analyzer was adjusted to receive the high frequency components of signals up to $\pm$ 5 mc on each side of the 60 mc center frequency. Without AFC the center frequency of the difference spectrum shifted continually, thereby requiring constant readjustment of the analyzer tuning for visual analysis.

Ambient temperature changes and power supply instability cause frequency drift and jitter of the klystron oscillator. When a superheterodyne receiver was used to detect the output of a klystron oscillator, the system instability was the sum of the instability of the transmitter plus the instability of the local oscillator in the receiver. An electronic frequency stabilization system was devised which could be easily adapted to existing power supplies. The use of the stabilization system eliminated long term drifts and jitter was reduced from 2.5 mc to 1 mc.

The AFC was designed to maintain a frequency difference of 60 mc between the local oscillator and the transmitter. The IF amplifier had a bandwidth of 10 mc centered at 60 mc, and was followed by a discriminator of 6 mc bandwidth centered at 60 mc (See Figure 4). The output of the discriminator was used to control the gain of a one stage audio amplifier. The input to this amplifier was connected to a 5 kc fixed amplitude oscillator. The amplitude of the 5 kc signal at the output of this amplifier was thus controlled by the output of the discriminator. The output of the variable gain amplifier was transformer coupled to a bridge rectifier and the output of the rectifier was connected in series with the reflector supply voltage for the local oscillator klystron. The transformer was used for isolation between the high voltage of the reflector supply and the output of the AFC stages. This method of coupling also provided a safety feature since the reflector voltage could not drop to zero if the AFC failed.

V. TEST RESULTS

A. Frequency Measurements

The data from each of the three test runs were averaged over ten second time intervals and plotted as shown in Figure 5. Results indicate that the best stability was obtained when both klystrons were powered by the same PRD supply. Maximum difference frequency recorded was 6.2 mc with the common supply, while, with the other two methods, the maximum frequency deviations recorded were 8.3 mc and 9.5 mc. The greatest deviation was observed when klystron No. 17 was powered by the FXR supply with an unregulated line voltage.

During all three tests, it was evident that warmup time and line voltage fluctuations influenced the frequency deviation to a marked degree. For those periods of the day when line loading was at a fairly constant level, the klystron frequency stability was better by a factor of nearly two over that when line loading fluctuated. This effect was observed by monitoring the 60 mc IF amplifier output around 1200 hours and 1600 hours.

The drift frequency during the warmup period from a cold start revealed that a decided stabilization of frequency occurred after about 2.5 hours. After 2.5 hours, the frequency was more stable by a factor of three than when initially turned on. Prior to this time, it was difficult to maintain a signal within 10 mc of an initial condition without continual readjustment of the klystron control voltages and mechanically retuning the klystron.

Figures 6 and 7 indicate the need for line regulation of the power used on the klystron power supply. The frequency deviation experienced with an unregulated power line is considerably decreased with the use of line regulation.

B. Spectrum Analysis

During the initial test, the difference frequency drifted out of the 10 mc bandpass of the 60 mc IF amplifier in a sporadic manner. The spectrum of the difference signal, as recorded photographically, is as wide as 1.5 mc at a 60 mc difference frequency. The sweep speed for all photographs was 1 per second. Certain klystron adjustments resulted in bursts of difference frequency over a bandwidth that exceeded 10 mc. This effect was observed during the retuning process to obtain a 60 mc difference frequency.

The inclusion of the AFC resulted in good control of the difference frequency. A difference frequency of 62 mc was observed to shift $\pm$ 1 mc during an interval of 1-3/4 hours. The spectrum of the 62 mc difference frequency was 5 mc wide.

Figure 8 is a reproduction of two spectrum analysis test photographs. The markers were set 10 mc apart. Frequency excursions having a rate less than 10 cycles per second were recorded. The horizontal and vertical scales were linear. The vertical scale was adjusted to bring the entire trace into view. Figure 8A is two photographs taken at a one minute interval. These two photographs of a 65 mc difference frequency show a spectrum about 1.3 mc wide. Figure 8B is another set of two photographs also taken at a one minute interval. This set of photographs shows a 71 mc difference frequency having a spectrum about 1.3 mc wide.

John E. Kammerer
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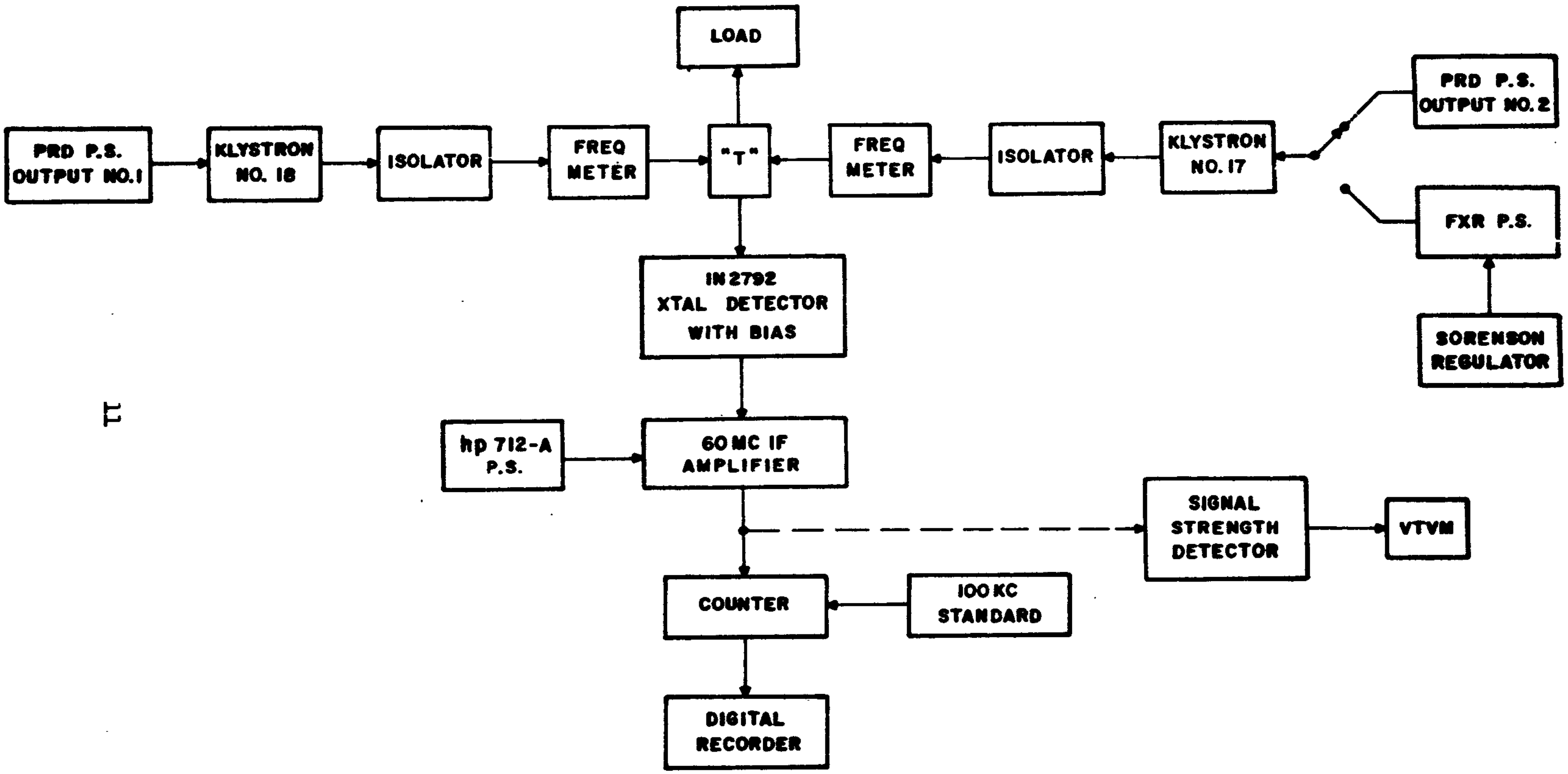

FIGURE 1 TEST SET - 70 Gc DIFFERENCE FREQUENCY COUNT

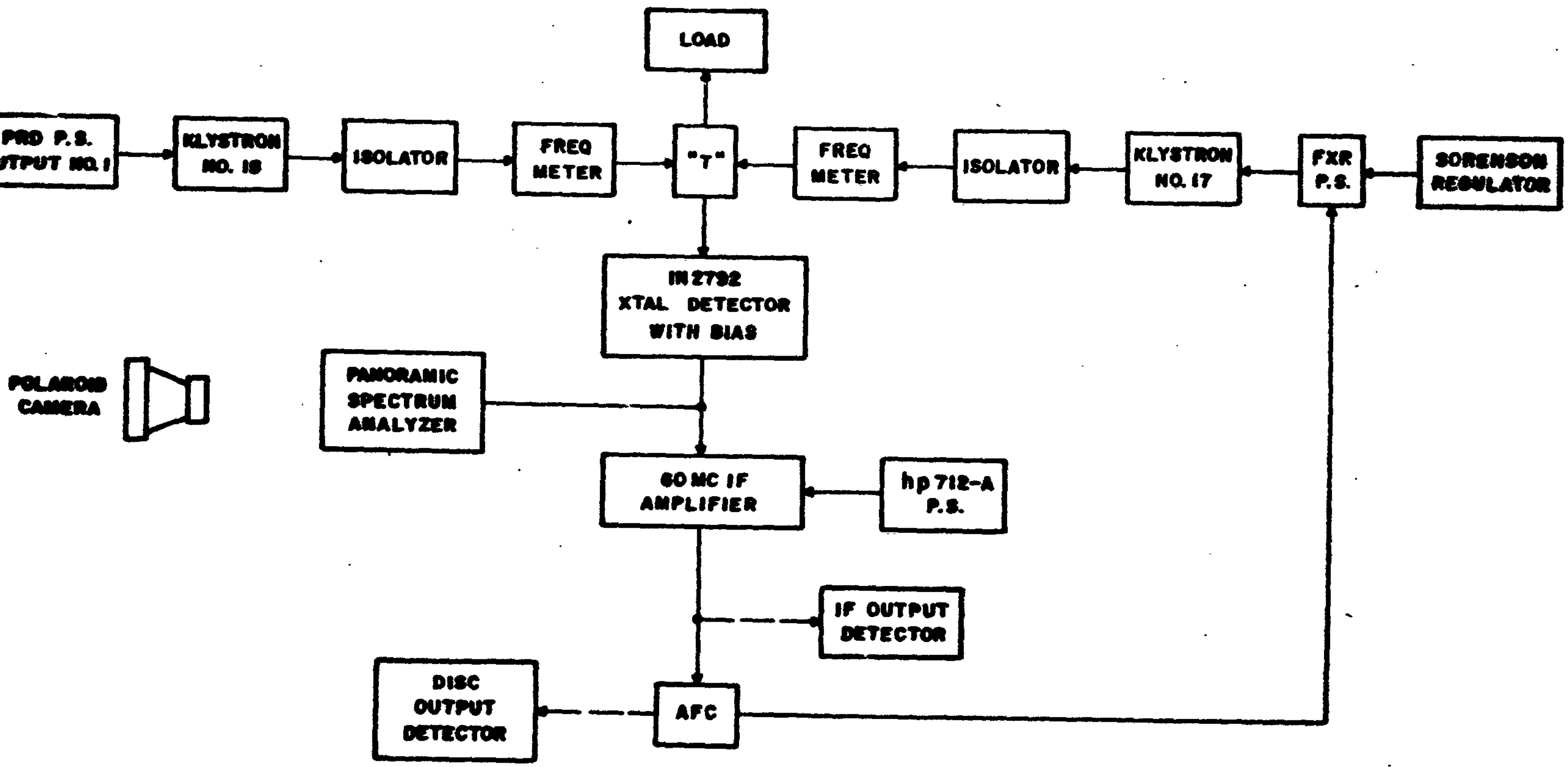

FIGURE 2 TEST SET – 70 Gc DIFFERENCE FREQUENCY SPECTRUM ANALYSIS

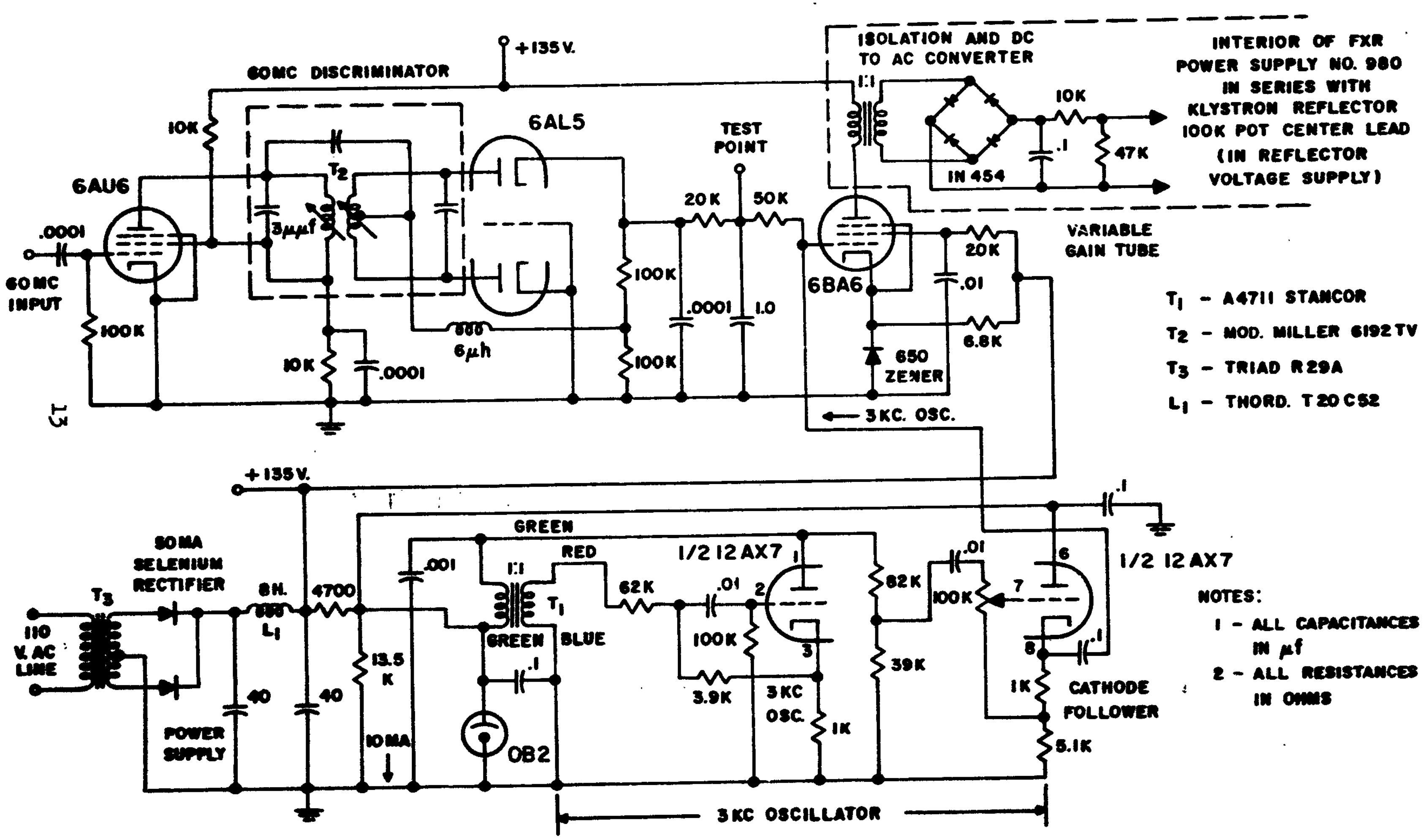

FIGURE 3 SCHEMATIC, AUTOMATIC FREQUENCY CONTROL UNIT

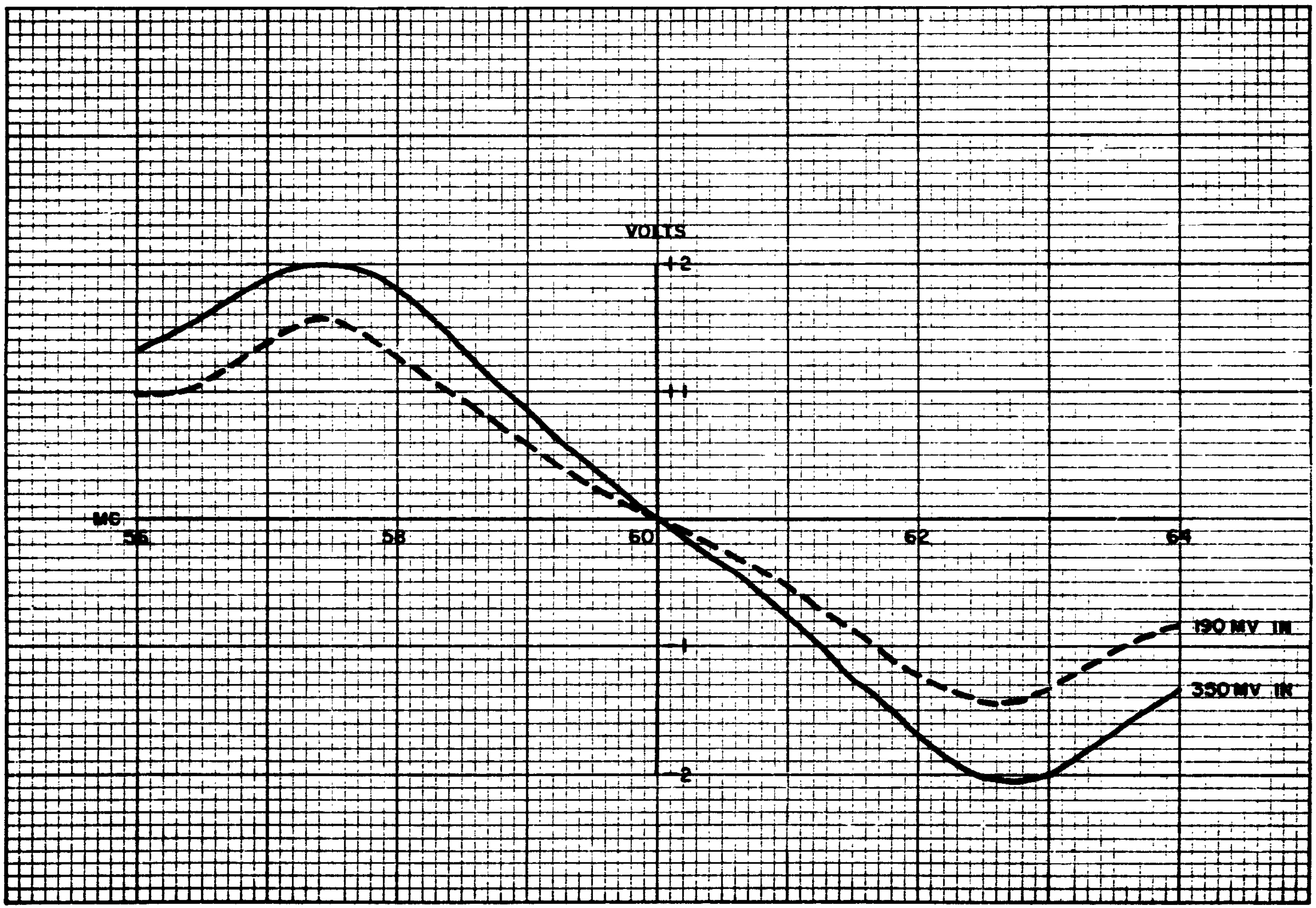

FIGURE 4 AFC DISCRIMINATOR OUTPUT CURVE

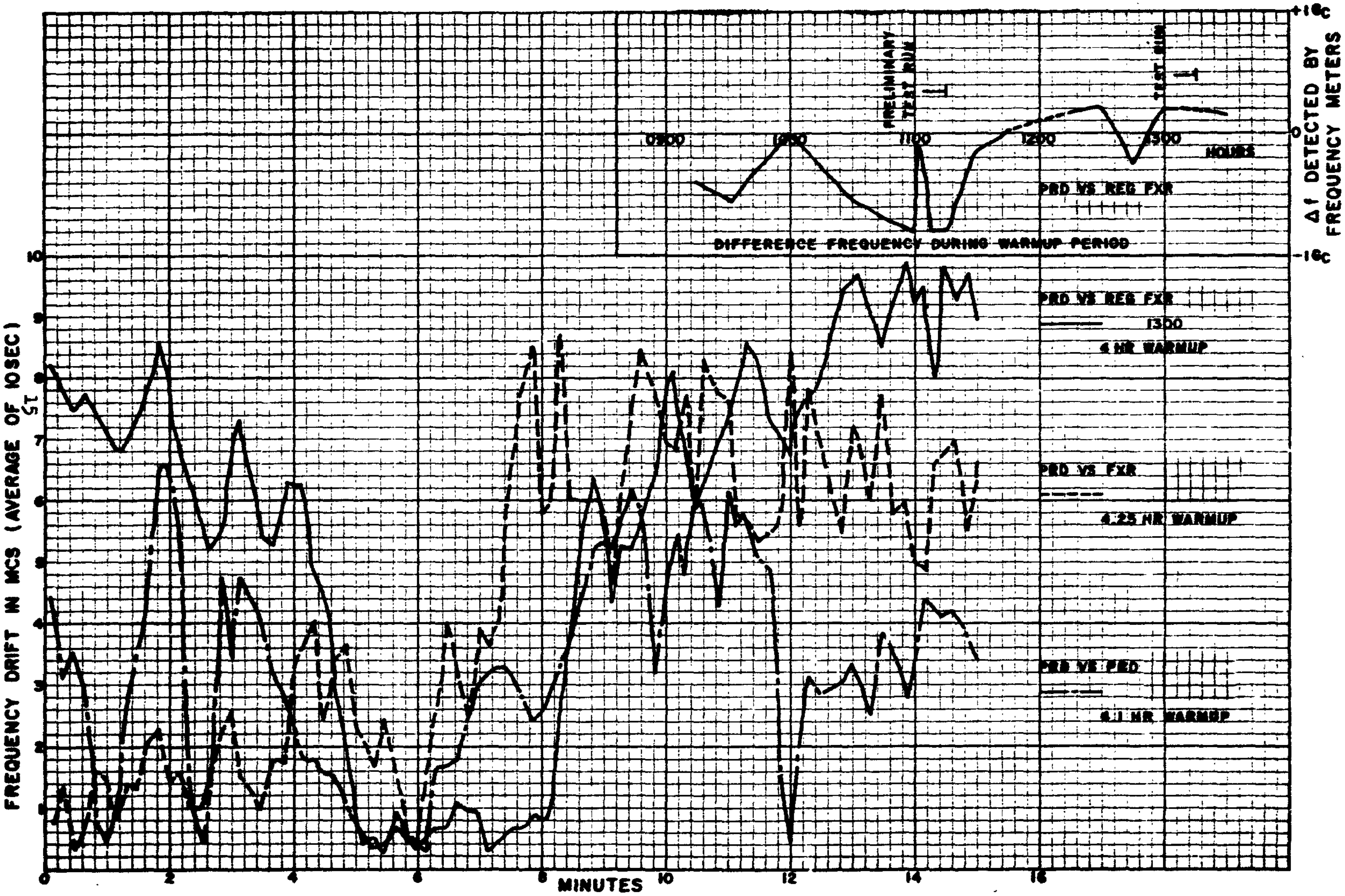

FIGURE 5 70G$_c$ DIFFERENCE FREQUENCY COUNT PLOT

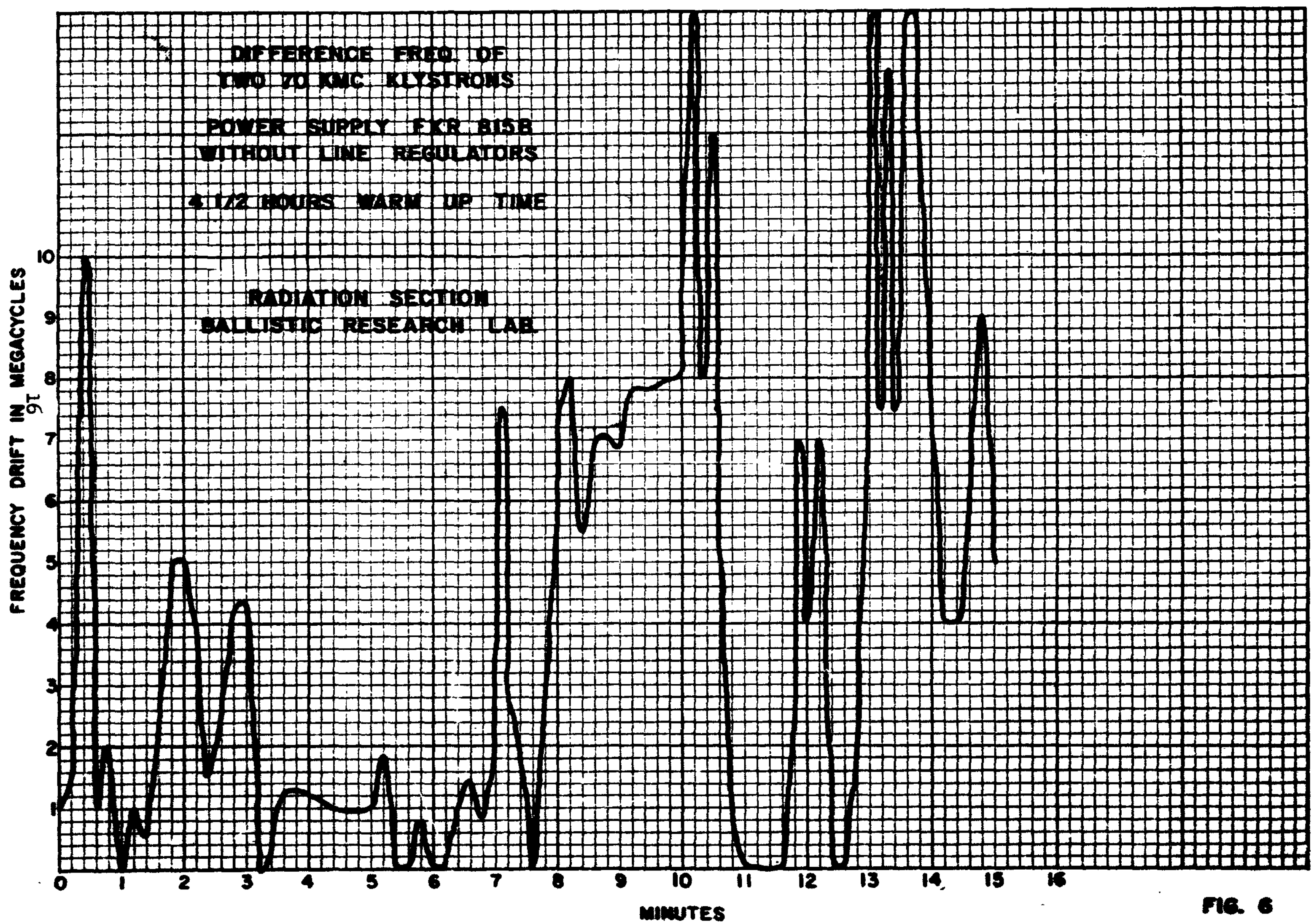
DIFFERENCE FREQ. OF
TWO 70 KMC KLYSTRONS
POWER SUPPLY FXR 815B
WITHOUT LINE REGULATORS
4 1/2 HOURS WARM UP TIME
RADIATION SECTION
BALLISTIC RESEARCH LAB.
FREQUENCY DRIFT IN MEGACYCLES
MINUTES
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

FIG. 6

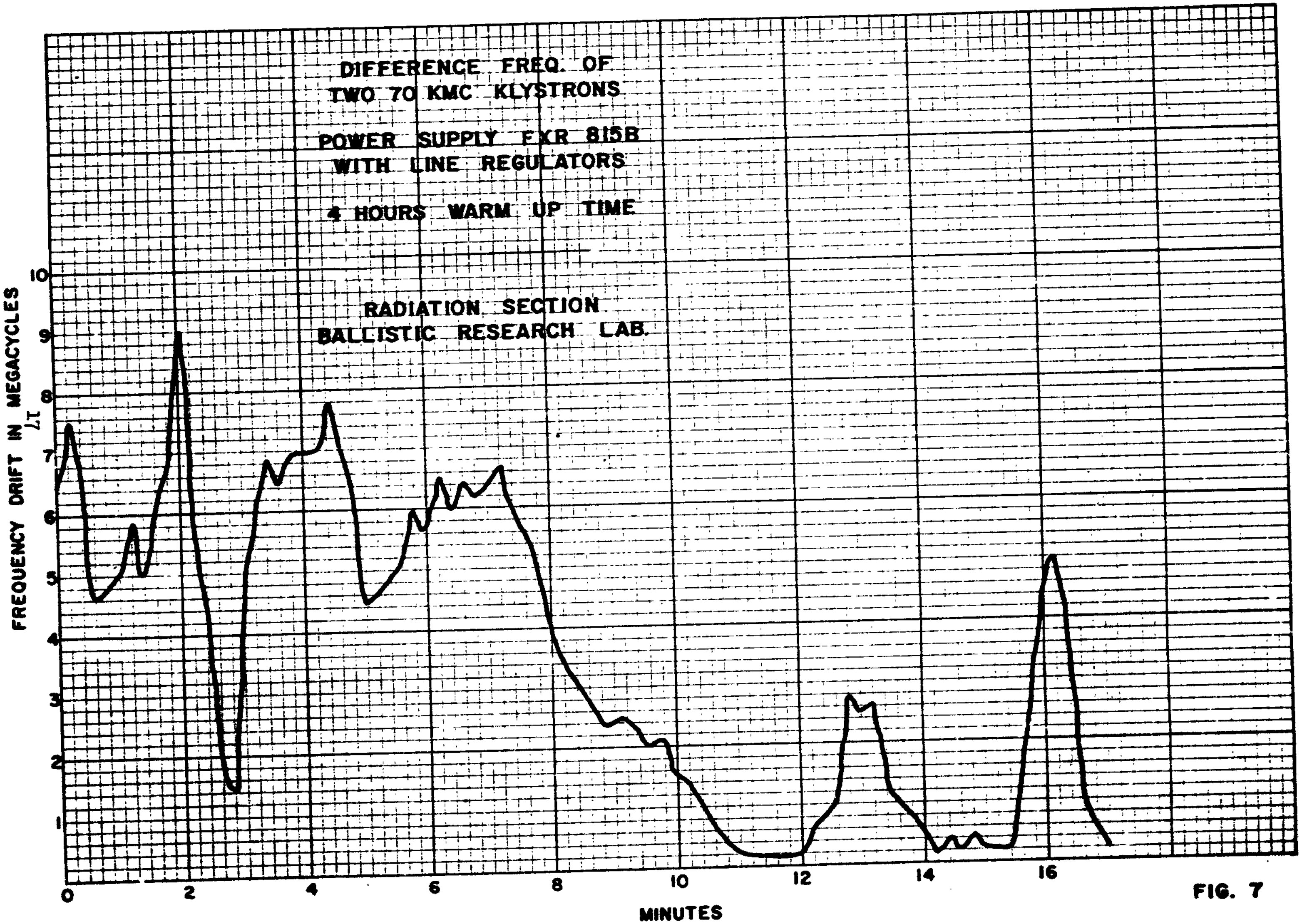
DIFFERENCE FREQ. OF
TWO 70 KMC KLYSTRONS
POWER SUPPLY FXR 815B
WITH LINE REGULATORS
4 HOURS WARM UP TIME
RADIATION SECTION
BALLISTIC RESEARCH LAB.
FREQUENCY DRIFT IN MEGACYCLES
MINUTES
0
2
4
6
8
10
12
14
16
1
2
3
4
5
6
7
8
9
10

FIG. 7

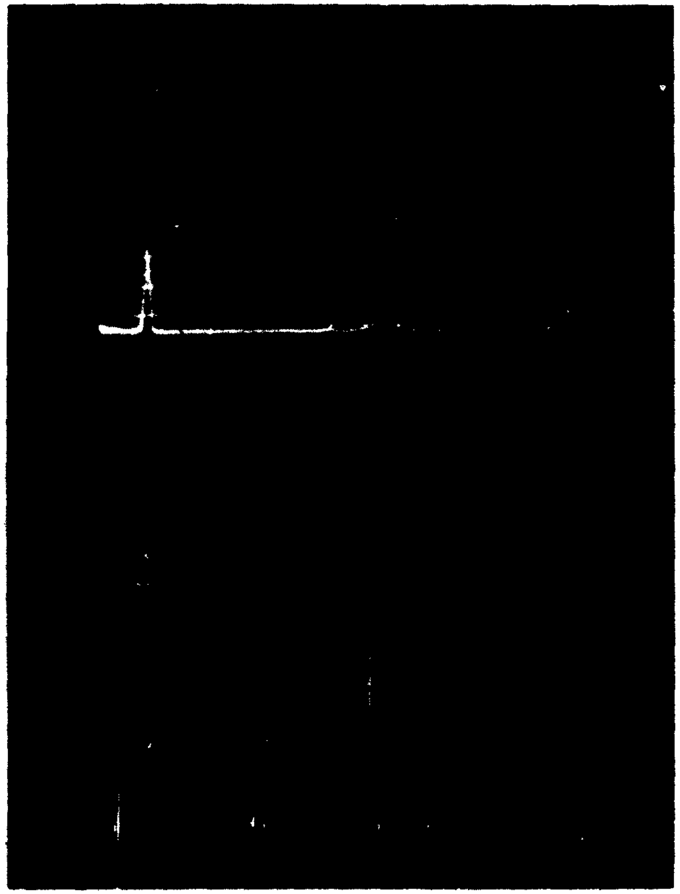

FIGURE 8A

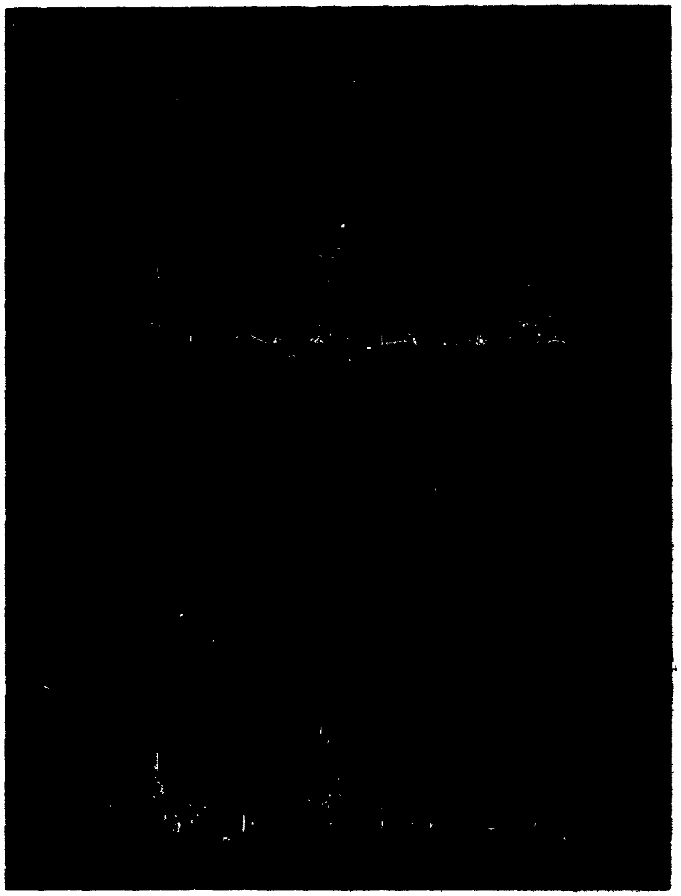

FIGURE 8B

FIGURE 8

QKK837 FREQUENCY SPECTRUM

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Electron tubes - Performance

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